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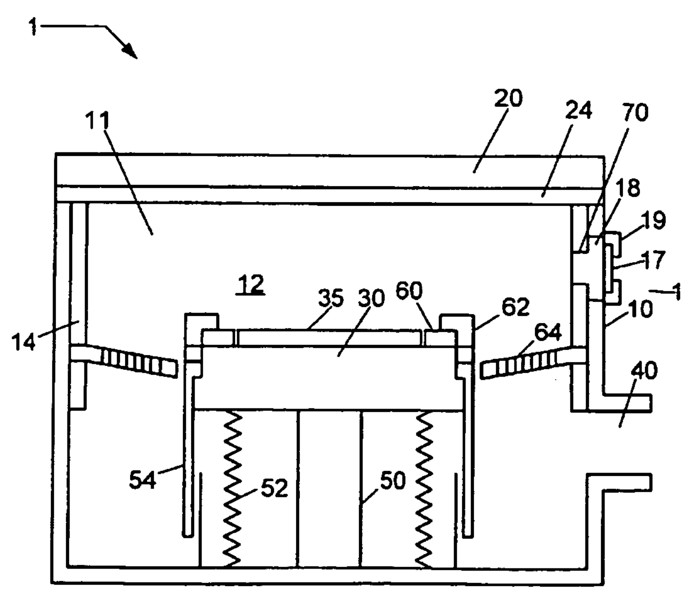
(54) Title: METHOD AND APPARATUS FOR AN IMPROVED UPPER ELECTRODE PLATE IN A PLASMA PROCESSING SYSTEM



(57) Abstract: The present invention presents an improved upper electrode for a plasma processing system, wherein the design and fabrication of an electrode plate coupled to an upper assembly advantageously provides gas injection of a process gas with substantially minimal erosion of the electrode plate.

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METHOD AND APPARATUS FOR AN IMPROVED UPPER ELECTRODE PLATE IN A PLASMA PROCESSING SYSTEM

Cross-reference to Related Applications

[0001] This application is related to co-pending United States patent application serial no. 10/XXX,XXX, entitled "Method and apparatus for an improved upper electrode plate with deposition shield in a plasma processing system", Attorney docket no. 226272US6YA, filed on even date herewith; co-pending United States patent application serial no. 10/XXX,XXX, entitled "Method and apparatus for an improved baffle plate in a plasma processing system", Attorney docket no. 226274US6YA, filed on even date herewith; co-pending United States patent application serial no. 10/XXX,XXX, entitled "Method and apparatus for an improved baffle plate in a plasma processing system", Attorney docket no. 228411US6YA, filed on even date herewith; co-pending United States patent application serial no. 10/XXX,XXX, entitled "Method and apparatus for an improved deposition shield in a plasma processing system", Attorney docket no. 226275US6YA, filed on even date herewith; co-pending United States patent application serial no. 10/XXX,XXX, entitled "Method and apparatus for an improved optical window deposition shield in a plasma processing system", Attorney docket no. 226276US6YA, filed on even date herewith; and co-pending United States patent application serial no. 10/XXX,XXX, entitled "Method and apparatus for an improved bellows shield in a plasma processing system", Attorney docket no. 226277US6YA, filed on even date herewith. The entire contents of all of those applications are herein incorporated by reference in their entirety.

Field of the Invention

[0002] The present invention relates to an improved component for a plasma processing system and more particularly to an upper electrode employed in a plasma processing system to introduce a processing gas.

Background of the Invention

[0003] The fabrication of integrated circuits (IC) in the semiconductor industry typically employs plasma to create and assist surface chemistry within a plasma reactor necessary to remove material from and deposit material to a substrate. In general, plasma is formed within the plasma reactor under vacuum conditions by heating electrons to energies sufficient to sustain ionizing collisions with a supplied process gas. Moreover, the heated electrons can have energy sufficient to sustain dissociative collisions and, therefore, a specific set of gases under predetermined conditions (e.g., chamber pressure, gas flow rate, etc.) are chosen to produce a population of charged species and chemically reactive species suitable to the particular process being performed within the chamber (e.g., etching processes where materials are removed from the substrate or deposition processes where materials are added to the substrate).

[0004] Although the formation of a population of charged species (ions, etc.) and chemically reactive species is necessary for performing the function of the plasma processing system (i.e. material etch, material deposition, etc.) at the substrate surface, other component surfaces on the interior of the processing chamber are exposed to the physically and chemically active plasma and, in time, can erode. The erosion of exposed components in the plasma processing system can lead to a gradual degradation of the plasma processing performance and ultimately to complete failure of the system.

[0005] In order to minimize the damage sustained by exposure to the processing plasma, components of the plasma processing system, known to sustain exposure to the processing plasma, are coated with a protective barrier. For example, components fabricated from aluminum can be anodized to produce a surface layer of aluminum oxide, which is more resistant to the plasma. In another example, a consumable or replaceable component, such as one fabricated from silicon, quartz, alumina, carbon, or silicon carbide, can be inserted within the processing chamber to protect the surfaces of more valuable components that would impose greater costs during frequent replacement. Furthermore, it is desirable to select surface materials that minimize the introduction of unwanted contaminants, impurities, etc. to the processing plasma and possibly to the devices formed on the substrate.

[0006] In both cases, the inevitable failure of the protective coating, either due to the integrity of the protective barrier or the integrity of the fabrication of the protective barrier, and the consumable nature of the replaceable components demands frequent maintenance of the plasma processing system. This frequent maintenance can produce costs associated with plasma processing down-time and new plasma processing chamber components, which can be excessive.

Summary of the Invention

[0007] The present invention provides an improved upper electrode for a plasma processing system, wherein the design and fabrication of the upper electrode advantageously addresses the above-identified shortcomings.

[0008] It is an object of the present invention to provide an electrode plate configured to be coupled to an upper assembly of a plasma processing system comprising a first surface for coupling the electrode plate to the upper assembly, a second surface, opposite the first surface, comprising a plasma surface configured to face a processing plasma in the plasma processing system and a mating surface for mating with the plasma processing system, and a peripheral edge.

[0009] The electrode plate further comprises one or more gas injection orifices, wherein each gas injection orifice comprises an entrant region for receiving a processing gas and an exit region for coupling the processing gas to the plasma processing system, the exit region comprising an injection surface.

[0010] The electrode plate further includes a plurality of fastening receptors for receiving fastening devices in order to attach the electrode plate to the upper assembly.

[0011] The electrode plate further includes a plenum cavity coupled to the first surface, configured to receive the processing gas, and configured to distribute the processing gas to the one or more gas injection orifices.

[0012] The electrode plate further includes a first sealing feature coupled to the first surface of the electrode plate and configured to seal the electrode plate with the upper assembly.

[0013] The electrode plate can further comprise a diagnostics port, and a second sealing feature coupled to the first surface of the electrode plate and configured to

seal the diagnostics port with the upper assembly. The diagnostics port can include an entrant cavity and an exit through-hole comprising an interior surface.

[0014] The electrode plate further comprises a protective barrier formed on a plurality of exposed surfaces of the electrode plate facing the processing plasma.

[0015] It is a further object of the present invention that the plurality of exposed surfaces of the electrode plate can comprise the plasma surface of the second surface of the electrode plate. Additionally, the exposed surfaces can further comprise the injection surface of the exit region in the one or more gas injection orifices, and the interior surface of the exit through-hole in the diagnostics port.

[0016] The present invention provides a method of producing the electrode plate in the plasma processing system comprising the steps: fabricating the electrode plate; anodizing the electrode plate to form a surface anodization layer on the electrode plate; machining the exposed surfaces on the electrode plate to remove the surface anodization layer; and forming a protective barrier on the exposed surfaces. The present invention may also optionally include machining the first surface of the electrode plate excluding the plenum cavity, the first sealing feature, and the second sealing feature.

[0017] The present invention provides another method of producing the electrode plate in the plasma processing system comprising the steps: fabricating the electrode plate; masking the exposed surfaces on the electrode plate to prevent formation of a surface anodization layer; anodizing the electrode plate to form the surface anodization layer on the electrode plate; unmasking the exposed surfaces; and forming a protective barrier on the exposed surfaces. The present invention may also optionally include masking other non-exposed surfaces (e.g., the first surface of the electrode plate excluding the plenum cavity, the first sealing feature, and the second sealing feature).

[0018] The present invention provides another method of producing the electrode plate for the upper electrode in the plasma processing system comprising the steps: fabricating the electrode plate; and forming a protective barrier on the exposed surfaces.

[0019] The present invention may also include a process of combining machining and masking to prepare the exposed surfaces to receive the protective barrier, and then forming the protective barrier on the exposed surfaces. For example, two of the exposed surfaces can be masked prior to anodizing, and two

of the surfaces can be machined after anodizing to create four exposed surfaces on which the protective barrier can be formed.

Brief Description of the Drawings

[0020] These and other advantages of the invention will become more apparent and more readily appreciated from the following detailed description of the exemplary embodiments of the invention taken in conjunction with the accompanying drawings, where:

[0021] FIG. 1 shows a simplified block diagram of a plasma processing system comprising an upper electrode including an electrode plate according to an embodiment of the present invention;

[0022] FIG. 2 shows a plan view of an electrode plate for a plasma processing system according to an embodiment of the present invention;

[0023] FIG. 3 shows a cross-sectional view of an electrode plate for the plasma processing system according to an embodiment of the present invention;

[0024] FIG. 4 shows an exploded view of a mating surface and a plasma surface of an electrode plate for the plasma processing system according to an embodiment of the present invention;

[0025] FIG. 5 shows an exploded view of a gas injection orifice in an electrode plate for the plasma processing system according to an embodiment of the present invention;

[0026] FIG. 6 shows an exploded view of an exit through-hole of a diagnostics port in an electrode plate for the plasma processing system according to an embodiment of the present invention;

[0027] FIG. 7 presents a method of producing an electrode plate for the plasma processing system according to an embodiment of the present invention;

[0028] FIG. 8 presents a method of producing an electrode plate for the plasma processing system according to another embodiment of the present invention; and

[0029] FIG. 9 presents a method of producing an electrode plate for the plasma processing system according to another embodiment of the present invention.

Detailed Description of an Embodiment

[0030] According to an embodiment of the present invention, a plasma processing system 1 is depicted in FIG. 1 comprising a plasma processing chamber 10, an upper assembly 20, an electrode plate 24, a substrate holder 30 for supporting a substrate 35, and a pumping duct 40 coupled to a vacuum pump (not shown) for providing a reduced pressure atmosphere 11 in plasma processing chamber 10. Plasma processing chamber 10 can facilitate the formation of a processing plasma in a process space 12 adjacent substrate 35. The plasma processing system 1 can be configured to process various substrates (i.e. 200 mm substrates, 300 mm substrates, or larger).

[0031] In the illustrated embodiment, upper assembly 20 can comprise at least one of a cover, a gas injection assembly, and an upper electrode impedance match network. For example, the electrode plate 24 can be coupled to an RF source, and facilitate an upper electrode for the plasma processing system 1. In another alternate embodiment, the upper assembly 20 comprises a cover and an electrode plate 24, wherein the electrode plate 24 is maintained at an electrical potential equivalent to that of the plasma processing chamber 10. For example, the plasma processing chamber 10, the upper assembly 20, and the electrode plate 24 can be electrically connected to ground potential, and facilitate an upper electrode for the plasma processing system 1.

[0032] Plasma processing chamber 10 can, for example, further comprise a deposition shield 14 for protecting the plasma processing chamber 10 from the processing plasma in the process space 12, and an optical viewport 16. Optical viewport 16 can comprise an optical window 17 coupled to the backside of an optical window deposition shield 18, and an optical window flange 19 can be configured to couple optical window 17 to the optical window deposition shield 18. Sealing members, such as O-rings, can be provided between the optical window flange 19 and the optical window 17, between the optical window 17 and the optical window deposition shield 18, and between the optical window deposition shield 18 and the plasma processing chamber 10. Optical window deposition shield 18 can extend through an opening 70 within deposition shield 14. Optical viewport 16 can, for example, permit monitoring of optical emission from the processing plasma in process space 12.

[0033] Substrate holder 30 can, for example, further comprise a vertical translational device 50 surrounded by a bellows 52 coupled to the substrate holder 30 and the plasma processing chamber 10, and configured to seal the vertical translational device 50 from the reduced pressure atmosphere 11 in plasma processing chamber 10. Additionally, a bellows shield 54 can, for example, be coupled to the substrate holder 30 and configured to protect the bellows 52 from the processing plasma. Substrate holder 10 can, for example, further be coupled to at least one of a focus ring 60, and a shield ring 62. Furthermore, a baffle plate 64 can extend about a periphery of the substrate holder 30.

[0034] Substrate 35 can be, for example, transferred into and out of plasma processing chamber 10 through a slot valve (not shown) and chamber feed-through (not shown) via robotic substrate transfer system where it is received by substrate lift pins (not shown) housed within substrate holder 30 and mechanically translated by devices housed therein. Once substrate 35 is received from substrate transfer system, it is lowered to an upper surface of substrate holder 30.

[0035] Substrate 35 can be, for example, affixed to the substrate holder 30 via an electrostatic clamping system. Furthermore, substrate holder 30 can, for example, further include a cooling system including a re-circulating coolant flow that receives heat from substrate holder 30 and transfers heat to a heat exchanger system (not shown), or when heating, transfers heat from the heat exchanger system. Moreover, gas can, for example, be delivered to the back-side of substrate 35 via a backside gas system to improve the gas-gap thermal conductance between substrate 35 and substrate holder 30. Such a system can be utilized when temperature control of the substrate is required at elevated or reduced temperatures. In other embodiments, heating elements, such as resistive heating elements, or thermo-electric heaters/coolers can be included.

[0036] In the illustrated embodiment, shown in FIG. 1, substrate holder 30 can comprise an electrode through which RF power is coupled to the processing plasma in process space 12. For example, substrate holder 30 can be electrically biased at a RF voltage via the transmission of RF power from a RF generator (not shown) through an impedance match network (not shown) to substrate holder 30. The RF bias can serve to heat electrons to form and maintain plasma. In this configuration, the system can operate as a reactive ion etch (RIE) reactor,

wherein the chamber and upper gas injection electrode serve as ground surfaces. A typical frequency for the RF bias can range from 1 MHz to 100 MHz and is preferably 13.56 MHz. RF systems for plasma processing are well known to those skilled in the art.

[0037] Alternately, the processing plasma formed in process space 12 can be formed using a parallel-plate, capacitively coupled plasma (CCP) source, an inductively coupled plasma (ICP) source, any combination thereof, and with and without DC magnet systems. Alternately, the processing plasma in process space 12 can be formed using electron cyclotron resonance (ECR). In yet another embodiment, the processing plasma in process space 12 is formed from the launching of a Helicon wave. In yet another embodiment, the processing plasma in process space 12 is formed from a propagating surface wave.

[0038] Referring now to an illustrated embodiment of the present invention depicted in FIG. 2 (plan view) and FIG. 3 (cross-sectional view), electrode plate 24 comprises a first surface 82 having a coupling surface 82a for coupling the electrode plate 24 to the upper assembly 20, a second surface 88 comprising a plasma surface 90 configured to face the processing plasma in the plasma processing chamber 10 and a mating surface 92 for mating the electrode plate 80 with the plasma processing chamber 10, and a peripheral edge 94.

[0039] FIG. 4 provides an expanded view of the mating surface 92 and the plasma surface 90 in proximity to the peripheral edge 94 of electrode plate 24.

[0040] With continuing reference to FIG. 2 and FIG. 3, and as shown in FIG. 5, the electrode plate 24 further includes one or more gas injection orifices 100 coupled to the plenum surface 82b and the second surface 88, wherein each gas injection orifice 100 comprises an entrant region 102 for receiving a processing gas and an exit region 104 for coupling the processing gas to the plasma processing chamber 10, the exit region 104 comprising an injection surface 106 contiguous with the plasma surface 90. The processing gas can, for example, comprise a mixture of gases such as argon, CF_4 and O_2, or argon, C_4F_8 and O_2 for oxide etch applications, or other chemistries such as, for example, $O_2/CO/Ar/C_4F_8$, $O_2/Ar/C_4F_8$, $O_2/CO/AR/C_5F_8$, $O_2/CO/Ar/C_4F_6$, $O_2/Ar/C_4F_6$, N_2/H_2, N_2/O_2.

[0041] For example, the number of gas injection orifices 100 formed within electrode plate 24 can range from 1 to 10000. Desirably, the number of gas

injection orifices 100 ranges from 50 to 500; and, preferably, the number of gas injection orifices 100 is at least 100. Furthermore, for example, a diameter of the gas injection orifice can range from 0.1 to 20 mm. Desirably, the diameter ranges from 0.5 to 5 mm, and preferably ranges from 0.5 to 2 mm. In addition, for example, a length of a gas injection orifice can range from 1 to 20 mm. Desirably, the length ranges from 2 to 15 mm, and preferably ranges from 3 to 12 mm.

[0042] Additionally, as shown in FIG. 3, electrode plate 24 comprises a plenum cavity 84 having a plenum surface 82b that is part of the first surface 82, configured to receive the processing gas, and configured to distribute the processing gas to the plurality of gas injection orifices 100.

[0043] Additionally, electrode plate 24 can comprise a first sealing feature 86 coupled to the coupling surface 82a of the electrode plate 24 and configured to seal the electrode plate 24 with the upper assembly 20. The first sealing feature can, for example, comprise a dovetail cross-section or rectangular cross-section configured for receiving an O-ring. In an alternate embodiment, an electrical coupling feature (not shown) can be integrated with the coupling surface 82a of the electrode plate 24 in order to provide improved electrical coupling between the electrode plate 24 and the upper electrode 20. The electrical coupling feature can, for example, comprise Spirashield (commercially available from Spira Manufacturing Company), known to those skilled in the art of vacuum processing.

[0044] The electrode plate 24 can further include a plurality of fastening receptors 110 for receiving fastening devices (such as bolts) (not shown) in order to attach the electrode plate 24 to the upper assembly 20. For example, the number of fastening receptors 110 formed within electrode plate 24 can range from 1 to 100. Desirably, the number of fastening receptors 110 can range from 5 to 20; and, preferably, the number of fastening receptors 110 is at least 8.

[0045] The electrode plate 24 can further comprise a diagnostics port 120, and a second sealing feature 122 coupled to the coupling surface 82a of the electrode plate 24 and configured to seal the diagnostics port 120 with the upper assembly 20. As depicted in FIG. 6, the diagnostics port 120 can include an entrant cavity 124 and an exit through-hole 126 comprising an interior surface 128 contiguous with the plasma surface 90. Similarly, the second sealing feature can, for example, comprise a dovetail cross-section or rectangular cross-section configured for receiving an O-ring. The diagnostics port 120 can be used to

couple a diagnostics system (not shown) with the reduced pressure atmosphere 11 of plasma processing chamber 10. For example, the diagnostics system can comprise a pressure manometer.

[0046] Additionally, electrode plate 24 can, for example, comprise one or more alignment features 130 in order to provide for proper coupling of the electrode plate 24 to the upper assembly 20. The one or more alignment features 130 can, for example, comprise two slots as shown in FIG. 2.

[0047] As illustrated in FIG. 5 and FIG. 6, a plurality of exposed surfaces 140 can comprise the plasma surface 90 of the second surface 88 of the electrode plate 24, the injection surface 106 of the one or more gas injection orifices 100, and the interior surface 128 of the diagnostics port 120. Alternately, the exposed surfaces comprise all surfaces on the electrode plate 24.

[0048] Referring now to FIGs. 2 through 6, the electrode plate 24 further comprises a protective barrier 150 formed on the exposed surfaces 140 of the electrode plate 24. In an embodiment of the present invention, the protective barrier 150 can comprise a compound including an oxide of aluminum such as Al_2O_3. In another embodiment of the present invention, the protective barrier 150 comprises a mixture of Al_2O_3 and Y_2O_3. In another embodiment of the present invention, the protective barrier 150 comprises at least one of a III-column element (column III of periodic table) and a Lanthanon element. In another embodiment of the present invention, the III-column element comprises at least one of Yttrium, Scandium, and Lanthanum. In another embodiment of the present invention, the Lanthanon element comprises at least one of Cerium, Dysprosium, and Europium. In another embodiment of the present invention, the compound forming protective barrier 150 comprises at least one of Yttria (Y_2O_3), Sc_2O_3, Sc_2F_3, YF_3, La_2O_3, CeO_2, Eu_2O_3, and DyO_3.

[0049] In an embodiment of the present invention, the protective barrier 150 formed on electrode plate 24 comprises a minimum thickness, wherein the minimum thickness can be specified as constant across at least one of the exposed surfaces 140. In another embodiment, the minimum thickness can be variable across the exposed surfaces 140. Alternately, the minimum thickness can be constant over a first portion of an exposed surface and variable over a second portion of the exposed surface. For example, a variable thickness can occur on a curved surface, on a corner, or in a hole. For example, the minimum

thickness can ranges from 0.5 micron to 500 micron. Desirably; the minimum thickness can range from 100 micron to 200 micron; and, preferably, the minimum thickness is at least 120 micron.

[0050] FIG. 7 presents a method of producing the electrode plate in the plasma processing system described in FIG. 1 according to an embodiment of the present invention. A flow diagram 300 begins in 310 with fabricating the electrode plate (e.g., an electrode plate having the characteristics of the plate described with reference to FIGs. 2-6). Fabricating the electrode plate can comprise at least one of machining, casting, polishing, forging, and grinding. For example, each of the elements described above can be machined according to specifications set forth on a mechanical drawing, using conventional techniques including a mill, a lathe, etc. The techniques for machining a component using, for example, a mill or a lathe, are well known to those skilled in the art of machining. The electrode plate can, for example, be fabricated from aluminum.

[0051] In 320, the electrode plate is anodized to form a surface anodization layer. For example, when fabricating the electrode plate from aluminum, the surface anodization layer comprises aluminum oxide (Al_2O_3). Methods of anodizing aluminum components are well known to those skilled in the art of surface anodization.

[0052] In 330, the surface anodization layer is removed from the exposed surfaces using standard machining techniques. During the same machining step, or during a separate machining step, other surfaces (e.g., the first surface of the electrode plate excluding the plenum cavity, the first sealing feature, and the second sealing feature) may also be machined (e.g., to produce a flat or bare surface that provides at least one of a good mechanical or electrical contact at the machined surface).

[0053] In 340, a protective barrier 150 (as described above) is formed on the exposed surfaces 140. A protective barrier comprising, for example Yttria, can be formed using (thermal) spray coating techniques that are well known to those skilled in the art of ceramic spray coatings. In an alternate embodiment, forming the protective barrier can further comprise polishing the thermal spray coating. For example, polishing the thermal spray coating can comprise the application of sand paper to the sprayed surfaces.

[0054] FIG. 8 presents a method of fabricating the electrode plate in the plasma processing system described in FIG. 1 according to another embodiment of the present invention. A flow diagram 400 begins in 410 with machining the electrode plate (e.g., an electrode plate having the characteristics of the plate described with reference to FIGs. 2-6). Fabricating the electrode plate can comprise at least one of machining, casting, polishing, forging, and grinding. For example, each of the elements described above can be machined according to specifications set forth on a mechanical drawing, using conventional techniques including a mill, a lathe, etc. The techniques for machining a component using, for example, a mill or a lathe, are well known to those skilled in the art of machining. The electrode plate can, for example, be fabricated from aluminum.

[0055] In 420, exposed surfaces 140 are masked to prevent the formation of a surface anodization layer thereon. Techniques for surface masking and unmasking are well known to those skilled in the art of surface coatings and surface anodization. During the same masking step, or during a separate masking step, other surfaces (e.g., the first surface of the electrode plate excluding the plenum cavity, the first sealing feature, and the second sealing feature) may also be masked (e.g., to maintain a flat or bare surface that provides at least one of a good mechanical or electrical contact at the machined surface).

[0056] In 430, the electrode plate is anodized to form a surface anodization layer on the remaining unmasked surfaces. For example, when fabricating the electrode plate with the deposition shield from aluminum, the surface anodization layer comprise aluminum oxide (Al_2O_3). Methods of anodizing aluminum components are well known to those skilled in the art of surface anodization.

[0057] In 440, the exposed surfaces 140 are unmasked, and a protective barrier 150 is formed on the exposed surfaces 140. A protective barrier comprising, for example Yttria, can be formed using (thermal) spray coating techniques that are well known to those skilled in the art of ceramic spray coatings. In an alternate embodiment, forming the protective barrier can further comprise polishing the thermal spray coating. For example, polishing the thermal spray coating can comprise the application of sand paper to the sprayed surfaces.

[0058] FIG. 9 presents a method of producing the electrode plate in the plasma processing system described in FIG. 1 according to another embodiment of the present invention. A flow diagram 500 begins in 510 with fabricating the electrode

plate (e.g., an electrode plate having the characteristics of the plate described with reference to FIGs. 2-6). Fabricating the electrode plate can comprise at least one of machining, casting, polishing, forging, and grinding. For example, each of the elements described above can be machined according to specifications set forth on a mechanical drawing, using conventional techniques including a mill, a lathe, etc. The techniques for machining a component using, for example, a mill or a lathe, are well known to those skilled in the art of machining. The electrode plate can, for example, be fabricated from aluminum.

[0059] In 520, a protective barrier 150 (as described above) is formed on the exposed surfaces 145 of the electrode plate. A protective barrier comprising, for example Yttria, can be formed using (thermal) spray coating techniques that are well known to those skilled in the art of ceramic spray coatings. In an alternate embodiment, forming the protective barrier can further comprise polishing the thermal spray coating. For example, polishing the thermal spray coating can comprise the application of sand paper to the sprayed surfaces.

[0060] In an alternate embodiment of the present invention, a mixture of masking and machining prepares the proper number of surfaces to be protected with a protective barrier 150. For example, the plasma surface of the second surface of the electrode plate may be masked to prevent an anodization layer from being formed thereon, while the injection surface of the exit region in the plurality of gas injection orifices is machined after anodization to present a bare, exposed surface.

[0061] While not necessary in order to form the protective barrier 150 on the exposed surfaces 140, it is also possible to machine other non-exposed surfaces on which an anodization layer has been formed or to mask other non-exposed surfaces prior to performing anodization (e.g., in order to provide a bare surface for an electrical or mechanical connection between parts). Such surfaces may include surfaces of sealing or mating features.

[0062] Although only certain exemplary embodiments of this invention have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention.

CLAIMS:

What is claimed is:

1. An upper electrode for a plasma processing system comprising:

an electrode plate comprising a first surface for coupling said electrode plate to an upper assembly, a second surface comprising a plasma surface configured to face a processing space in said plasma processing system and a mating surface for mating said electrode plate with said plasma processing system, a peripheral edge, and one or more gas injection orifices coupled to said first surface and said second surface and configured to couple a processing gas to said processing space; and

a protective barrier coupled to a plurality of exposed surfaces of said electrode plate, said exposed surfaces comprising said plasma surface.

2. The upper electrode as recited in claim 1, wherein said electrode plate further comprises a plenum cavity coupled to said first surface, configured to receive said processing gas, and configured to distribute said processing gas to said one or more gas injection orifices.

3. The upper electrode as recited in claim 1, wherein said electrode plate further comprises a first sealing feature coupled to said first surface and configured to seal said electrode plate to said upper assembly.

4. The upper electrode as recited in claim 1, wherein said electrode plate further comprises a diagnostics port for coupling a diagnostics system to said plasma processing system and a second sealing feature to seal said diagnostics port to said upper assembly.

5. The upper electrode as recited in claim 1, wherein said protective barrier comprises a compound containing at least one of a III-column element and a Lanthanon element.

6. The upper electrode as recited in claim 5, wherein said III-column element comprises at least one of Yttrium, Scandium, and Lanthanum.

7. The upper electrode as recited in claim 5, wherein said Lanthanon element comprises at least one of Cerium, Dysprosium, and Europium.

8. The upper electrode as recited in claim 1, wherein said protective barrier comprises at least one of Yttria (Y_2O_3), Sc_2O_3, Sc_2F_3, YF_3, La_2O_3, CeO_2, Eu_2O_3, and DyO_3.

9. The upper electrode as recited in claim 1, wherein said gas injection orifice comprises an entrant region, and an exit region, wherein said exit region comprises an injection surface.

10. The upper electrode as recited in claim 1, wherein said diagnostics port comprises an entrant cavity, and an exit through-hole, wherein said exit through-hole comprises an interior surface.

11. The upper electrode as recited in claim 9, wherein said protective barrier is coupled to said injection surface of said gas injection orifice.

12. The upper electrode as recited in claim 10, wherein said protective barrier is coupled to said interior surface of said fastening receptor.

13. The upper electrode as recited in claim 1, wherein said protective barrier comprises a minimum thickness and said minimum thickness is constant across at least one of said exposed surfaces.

14. The upper electrode as recited in claim 1, wherein said protective barrier comprises a variable thickness, said variable thickness ranging from 0.5 microns to 500 microns.

15. The upper electrode as recited in claim 1, wherein at least one gas injection orifice has a diameter that is at least 0.1 mm.

16. The upper electrode as recited in claim 1, wherein at least one gas injection orifice has a length that is at least 1.0 mm.

17. The upper electrode as recited in claim 9, wherein said exposed surfaces further comprise said injection surface of said one or more gas injection orifices.

18. The upper electrode as recited in claim 10, wherein said exposed surfaces further comprise said interior surface of said diagnostics port.

19. The upper electrode as recited in claim 1, said electrode plate further comprising a metal.

20. The upper electrode as recited in claim 19, wherein said metal comprises aluminum.

21. The upper electrode as recited in claim 1, wherein said first surface comprises an anodization layer.

22. The upper electrode as recited in claim 1, wherein said plenum cavity comprises an anodization layer.

23. The upper electrode as recited in claim 1, wherein said mating surface comprises a metallic surface.

24. A method of producing an electrode plate for a plasma processing system, said method comprising the steps:

fabricating said electrode plate, said electrode plate comprising a first surface for coupling said electrode plate to an upper assembly, a second surface comprising a plasma surface configured to face a processing space in said plasma processing system and a mating surface for mating said electrode plate with said plasma processing system, a peripheral edge of said electrode plate, and one or more gas injection orifices coupled to said first surface and said

second surface and configured to couple a processing gas to said processing space; and

forming a protective barrier on a plurality of exposed surfaces, said exposed surfaces comprising said plasma surface.

25. The method as recited in claim 24, wherein said method further comprises the steps:

anodizing said electrode plate to form a surface anodization layer on said electrode plate; and

machining said exposed surfaces on said electrode plate to remove said surface anodization layer prior to forming said protective barrier on said exposed surfaces.

26. The method as recited in claim 24, wherein said method further comprises the steps:

masking said exposed surfaces on said electrode plate;

anodizing said electrode plate to form a surface anodization layer on said electrode plate; and

unmasking said exposed surfaces prior to forming said protective barrier on said exposed surfaces.

27. The method as recited in claim 24, wherein said fabricating comprises at least one of machining, casting, polishing, forging, and grinding.

28. The method as recited in claim 24, wherein said forming said protective barrier further comprises polishing said protective barrier on at least one of said exposed surfaces.

29. The method as recited in claim 24, wherein said electrode plate further comprises a plenum cavity coupled to said first surface, configured to receive said processing gas, and configured to distribute said processing gas to said plurality of gas injection orifices.

30. The method as recited in claim 24, wherein said electrode plate further comprises a first sealing feature coupled to said first surface and configured to seal said electrode plate to said upper assembly.

31. The method as recited in claim 24, wherein said electrode plate further comprises a diagnostics port for coupling a diagnostics system to said plasma processing system and a second sealing feature to seal said diagnostics port to said upper assembly.

32. The method as recited in claim 24, wherein said gas injection orifice comprises an entrant region, and an exit region, wherein said exit region comprises an injection surface.

33. The method as recited in claim 31, wherein said diagnostics port comprises an entrant cavity, and an exit through-hole, wherein said exit through-hole comprises an interior surface.

34. The method as recited in claim 32, wherein said exposed surfaces further comprise said injection surface of said one or more gas injection orifices.

35. The method as recited in claim 33, wherein said exposed surfaces further comprise said interior surface of said diagnostics port.

36. The method as recited in claim 24, said electrode plate further comprising a metal.

37. The method as recited in claim 36, wherein said metal comprises aluminum.

38. The method as recited in claim 24, wherein said protective barrier comprises a compound containing at least one of a III-column element and a Lanthanon element.

39. The method as recited in claim 38, wherein said III-column element comprises at least one of Yttrium, Scandium, and Lanthanum.

40. The method as recited in claim 38, wherein said Lanthanon element comprises at least one of Cerium, Dysprosium, and Europium.

41. The method as recited in claim 24, wherein said protective barrier comprises at least one of Yttria (Y_2O_3), Sc_2O_3, Sc_2F_3, YF_3, La_2O_3, CeO_2, Eu_2O_3, and DyO_3.

42. The method as recited in claim 24, wherein said protective barrier comprises a minimum thickness and said minimum thickness is constant across at least one of said exposed surfaces.

43. The method as recited in claim 24, wherein said protective barrier comprises a varible thickness and said variable thickness ranging from 0.5 microns to 500 microns.

44. The method as recited in claim 24, wherein said first surface comprises an anodization layer.

45. The method as recited in claim 24, wherein said plenum cavity comprises an anodization layer.

46. The method as recited in claim 49, wherein said mating surface comprises a metallic surface.

47. The method as recited in claim 24, wherein at least one gas injection orifice has a diameter that is at least 0.1 mm.

48. The method as recited in claim 24, wherein at least one gas injection orifice has a length that is at least 1.0 mm.

49. The method as recited in claim 24, wherein said fabricating comprises at least one of machining, casting, polishing, forging, and grinding.

50. The method as recited in claim 24, wherein said forming a protective barrier further comprises polishing at least one of said exposed surfaces.

51. The method as recited in claim 24, wherein said exposed surfaces further comprise all surfaces remaining on said electrode plate.

52. A method of producing an electrode plate capable of being coupled to an upper assembly of a plasma processing system, said method comprising the steps:

fabricating said electrode plate, said electrode plate comprising a first surface for coupling said electrode plate to said upper assembly, a second surface comprising a plasma surface configured to face a processing space in said plasma processing system and a mating surface for mating said electrode plate with said plasma processing system, a peripheral edge of said electrode plate, and one or more gas injection orifices coupled to said first surface and said second surface and configured to couple a processing gas to said processing space;

anodizing said electrode plate to form a surface anodization layer on said electrode plate;

machining exposed surfaces on said electrode plate to remove said surface anodization layer, said exposed surfaces comprising said plasma surface of said second surface of said electrode plate; and

forming a protective barrier on the exposed surfaces.

53. The method as recited in claim 52, wherein said electrode plate further comprises a plenum cavity coupled to said first surface, configured to receive said processing gas, and configured to distribute said processing gas to said one or more gas injection orifices.

54. The method as recited in claim 52, wherein said electrode plate further comprises a first sealing feature coupled to said first surface and configured to seal said electrode plate to said upper assembly.

55. The method as recited in claim 52, wherein said electrode plate further comprises a diagnostics port for coupling a diagnostics system to said plasma processing system and a second sealing feature to seal said diagnostics port to said upper assembly.

56. The method as recited in claim 52, wherein said protective barrier comprises a compound containing at least one of a III-column element and a Lanthanon element.

57. The method as recited in claim 56, wherein said III-column element comprises at least one of Yttrium, Scandium, and Lanthanum.

58. The method as recited in claim 56, wherein said Lanthanon element comprises at least one of Cerium, Dysprosium, and Europium.

59. The method as recited in claim 56, wherein said compound comprises Yttria (Y_2O_3), Sc_2O_3, Sc_2F_3, YF_3, La_2O_3, CeO_2, Eu_2O_3, and DyO_3.

60. The method as recited in claim 52, wherein said fabricating comprises at least one of machining, casting, polishing, forging, and grinding.

61. The method as recited in claim 52, wherein said forming a protective barrier further comprises polishing said protective barrier on at least one of said exposed surfaces.

62. The method as recited in claim 52, wherein said gas injection orifice comprises an entrant region, and an exit region, wherein said exit region comprises an injection surface.

63. The method as recited in claim 55, wherein said diagnostics port comprises an entrant cavity, and an exit through-hole, wherein said exit through-hole comprises an interior surface.

64. The method as recited in claim 62, wherein said exposed surfaces further comprise said injection surface of said one or more gas injection orifices.

65. The method as recited in claim 63, wherein said exposed surfaces further comprise said interior surface of said diagnostics port.

66. A method of producing an electrode plate capable of being coupled to an upper assembly of a plasma processing system, said method comprising the steps:

fabricating said electrode plate, said electrode plate comprising a first surface for coupling said electrode plate to said upper assembly, a second surface comprising a plasma surface configured to face a processing space in said plasma processing system and a mating surface for mating said electrode plate with said plasma processing system, a peripheral edge of said electrode plate, and one or more gas injection orifices coupled to said first surface and said second surface and configured to couple a processing gas to said processing space;

masking exposed surfaces on said electrode plate to prevent formation of a surface anodization layer, said exposed surfaces comprising said plasma surface of said second surface of said electrode plate;

anodizing said electrode plate to form said surface anodization layer on said electrode plate;

unmasking said exposed surfaces; and

forming a protective barrier on the exposed surfaces.

67. The method as recited in claim 66, wherein said electrode plate further comprises a plenum cavity coupled to said first surface, configured to receive said processing gas, and configured to distribute said processing gas to said one or more gas injection orifices.

68. The method as recited in claim 66, wherein said electrode plate further comprises a first sealing feature coupled to said first surface and configured to seal said electrode plate to said upper assembly.

69. The method as recited in claim 66, wherein said electrode plate further comprises a diagnostics port for coupling a diagnostics system to said plasma processing system and a second sealing feature to seal said diagnostics port to said upper assembly.

70. The method as recited in claim 66, wherein said protective barrier comprises a compound containing at least one of a III-column element and a Lanthanon element.

71. The method as recited in claim 67, wherein said III-column element comprises at least one of Yttrium, Scandium, and Lanthanum.

72. The method as recited in claim 67, wherein said Lanthanon element comprises at least one of Cerium, Dysprosium, and Europium.

73. The method as recited in claim 67, wherein said compound comprises Yttria (Y_2O_3), Sc_2O_3, Sc_2F_3, YF_3, La_2O_3, CeO_2, Eu_2O_3, and DyO_3.

74. The method as recited in claim 66, wherein said fabricating comprises at least one of machining, casting, polishing, forging, and grinding.

75. The method as recited in claim 66, wherein said forming a protective barrier further comprises polishing said protective barrier on at least one of said exposed surfaces.

76. The method as recited in claim 66, wherein said gas injection orifice comprises an entrant region, and an exit region, wherein said exit region comprises an injection surface.

77. The method as recited in claim 69, wherein said diagnostics port comprises an entrant cavity, and an exit through-hole, wherein said exit through-hole comprises an interior surface.

78. The method as recited in claim 76, wherein said exposed surfaces further comprise said injection surface of said one or more gas injection orifices.

79. The method as recited in claim 77, wherein said exposed surfaces further comprise said interior surface of said diagnostics port.

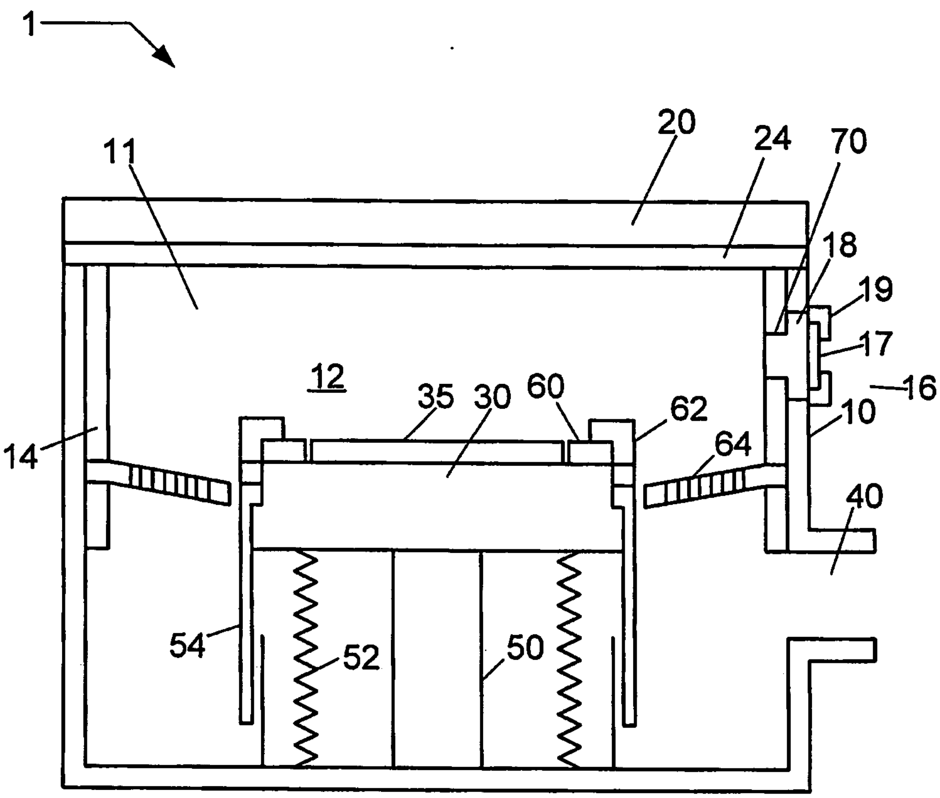


FIG. 1.

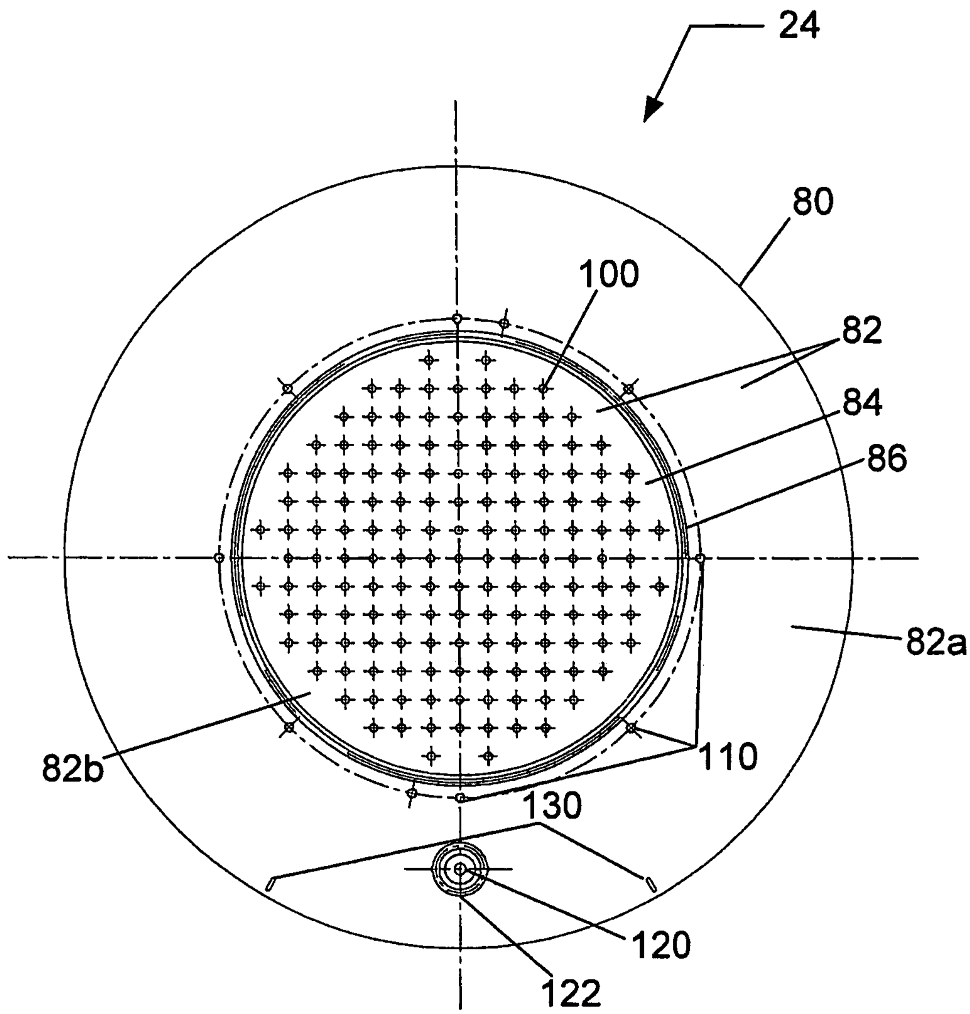
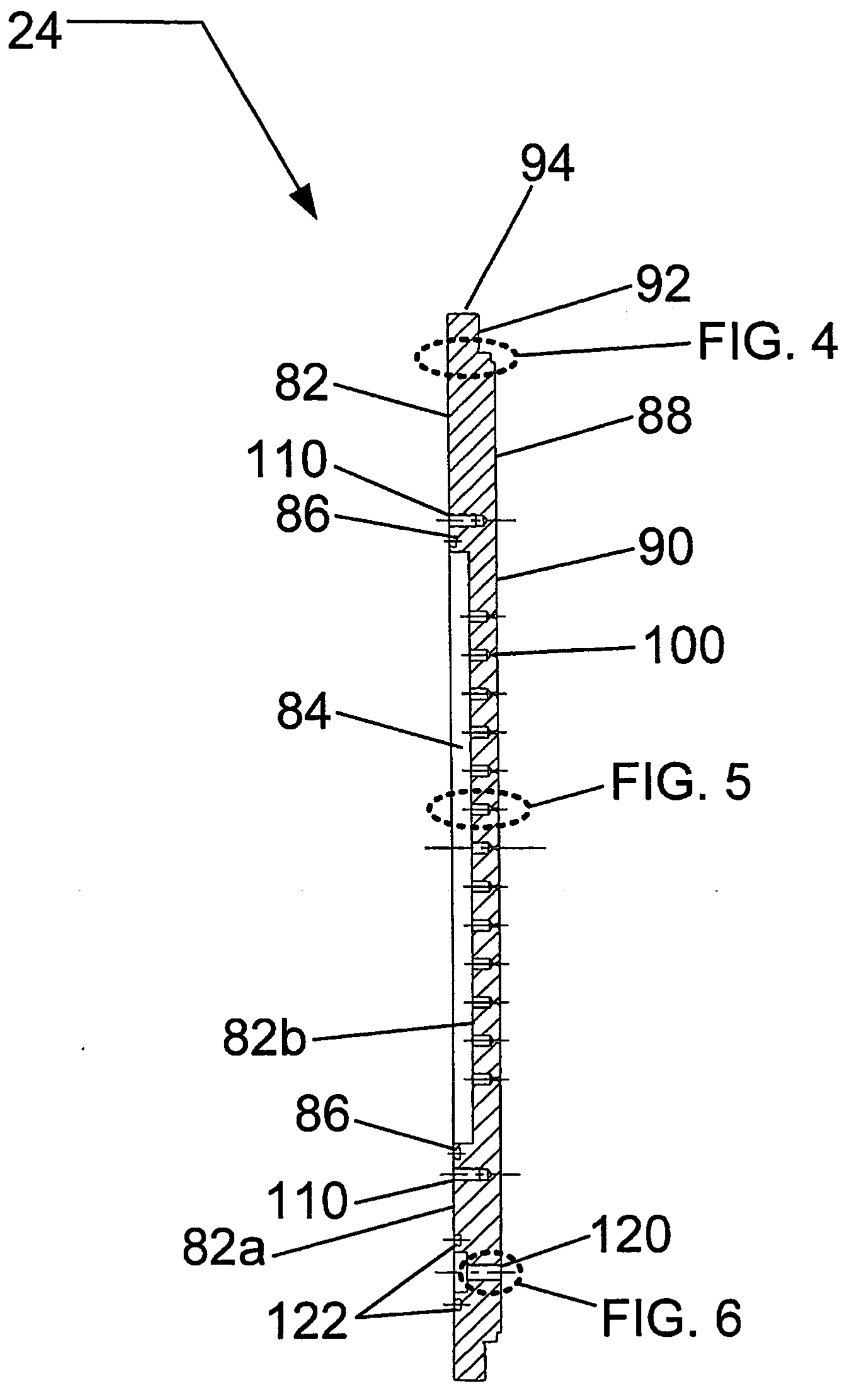


FIG. 2.



24
94
92
FIG. 4
82
88
110
86
90
100
84
FIG. 5
82b
86
110
82a
120
122
FIG. 6

FIG. 3.

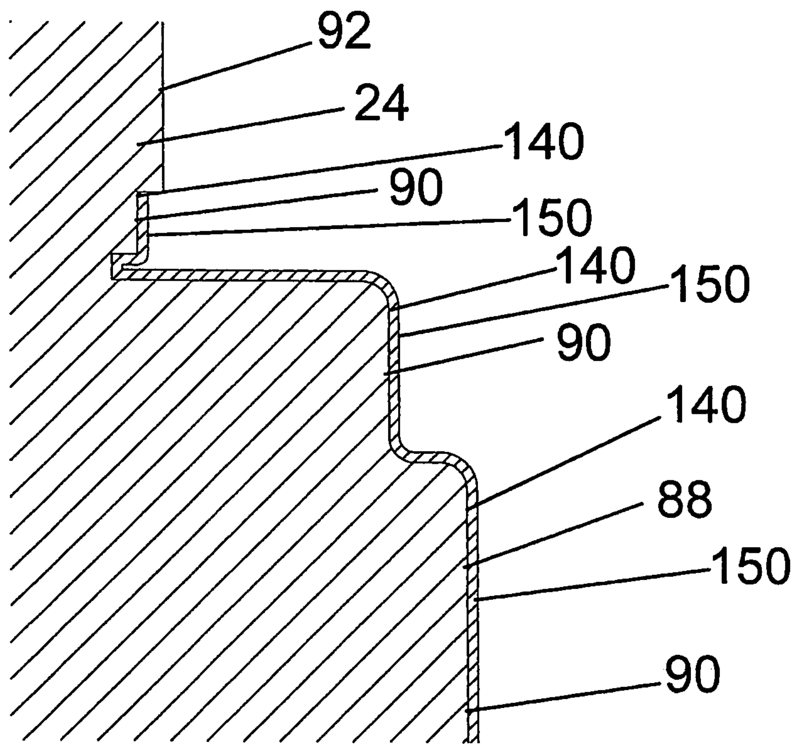


FIG. 4.

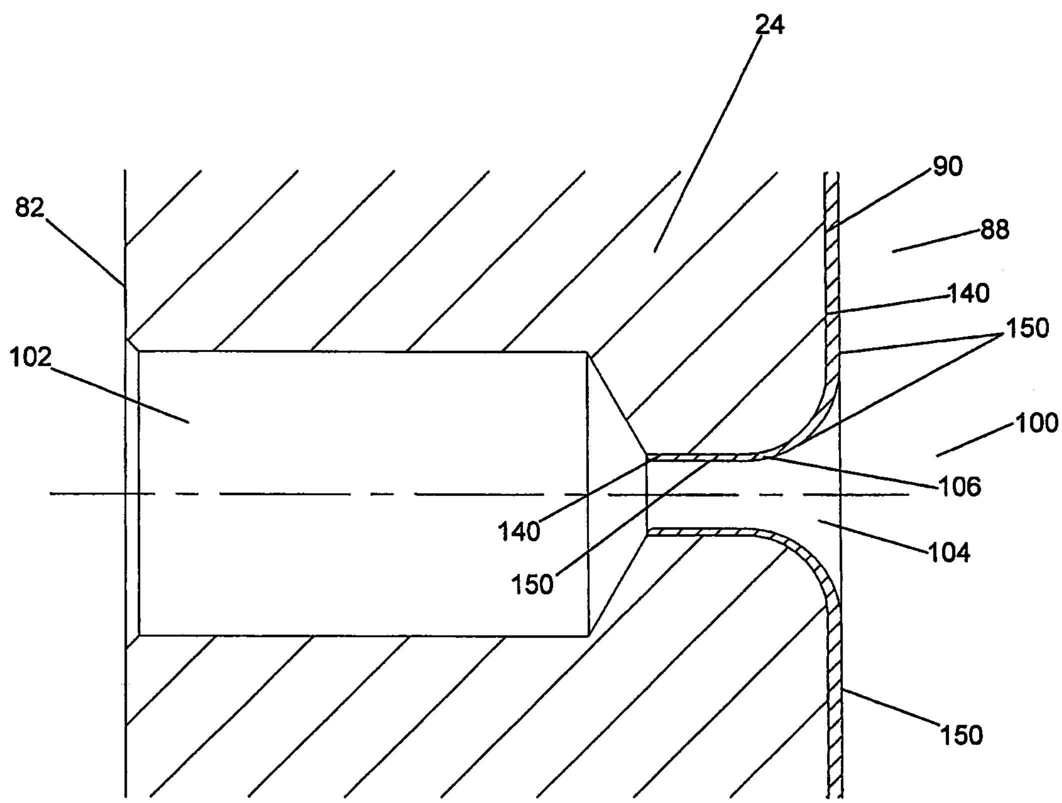


FIG. 5.

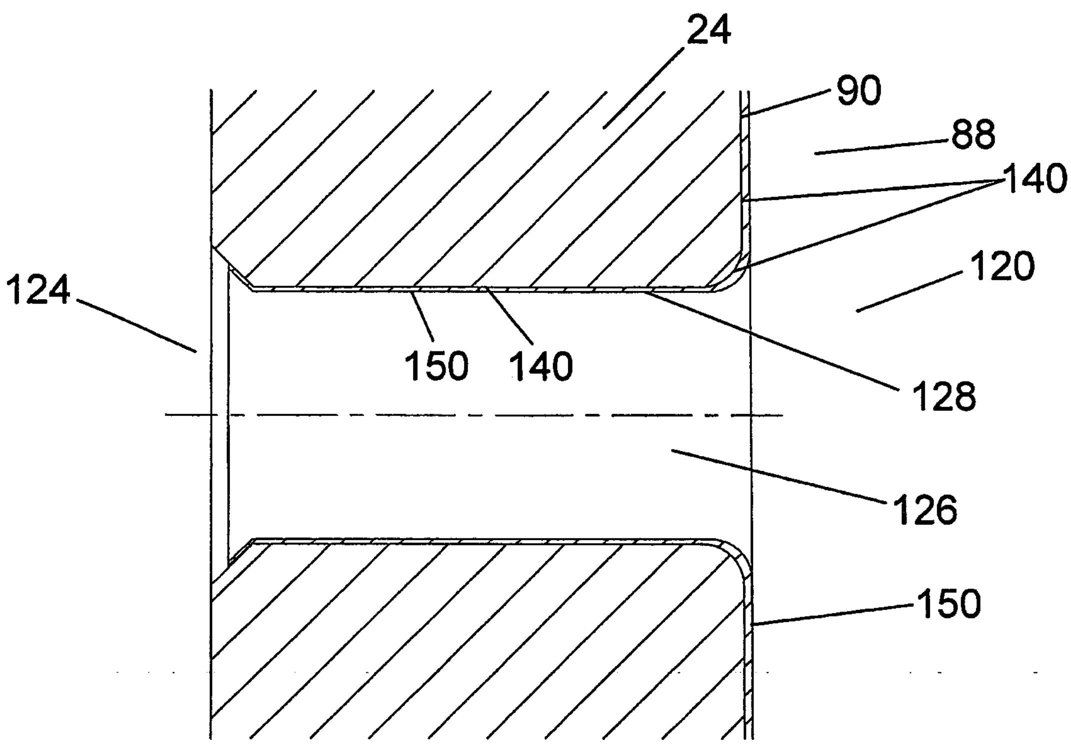


FIG. 6.

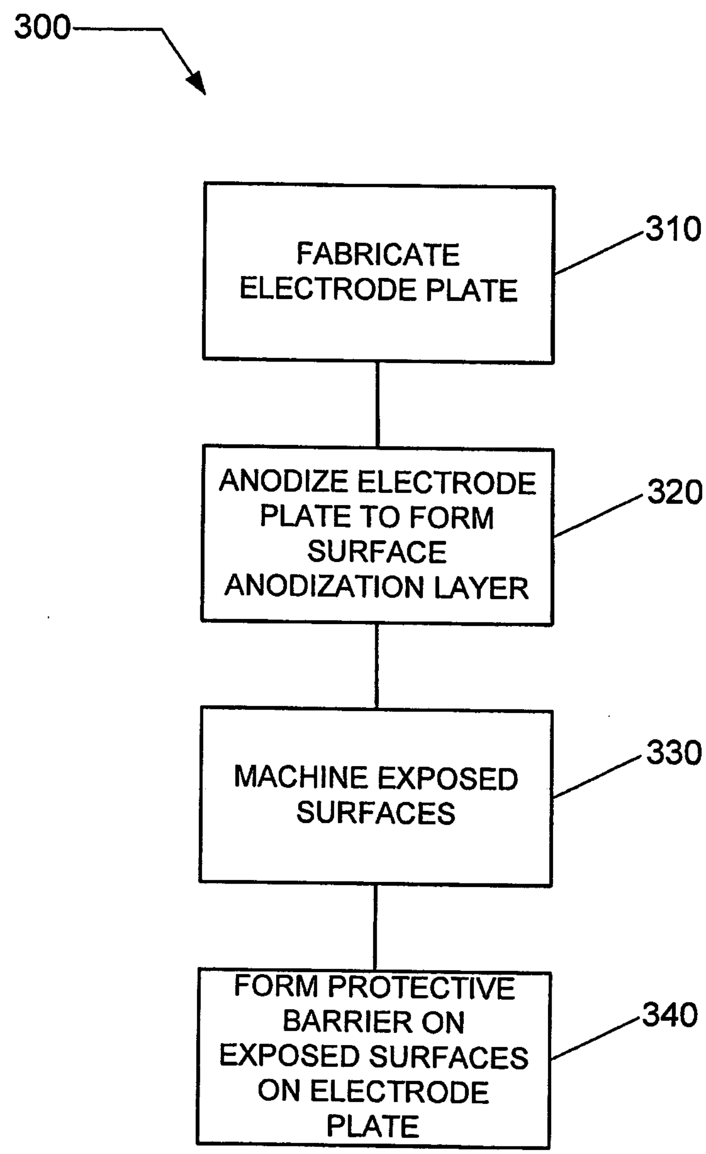

300
FABRICATE ELECTRODE PLATE
310
ANODIZE ELECTRODE PLATE TO FORM SURFACE ANODIZATION LAYER
320
MACHINE EXPOSED SURFACES
330
FORM PROTECTIVE BARRIER ON EXPOSED SURFACES ON ELECTRODE PLATE
340

FIG. 7.

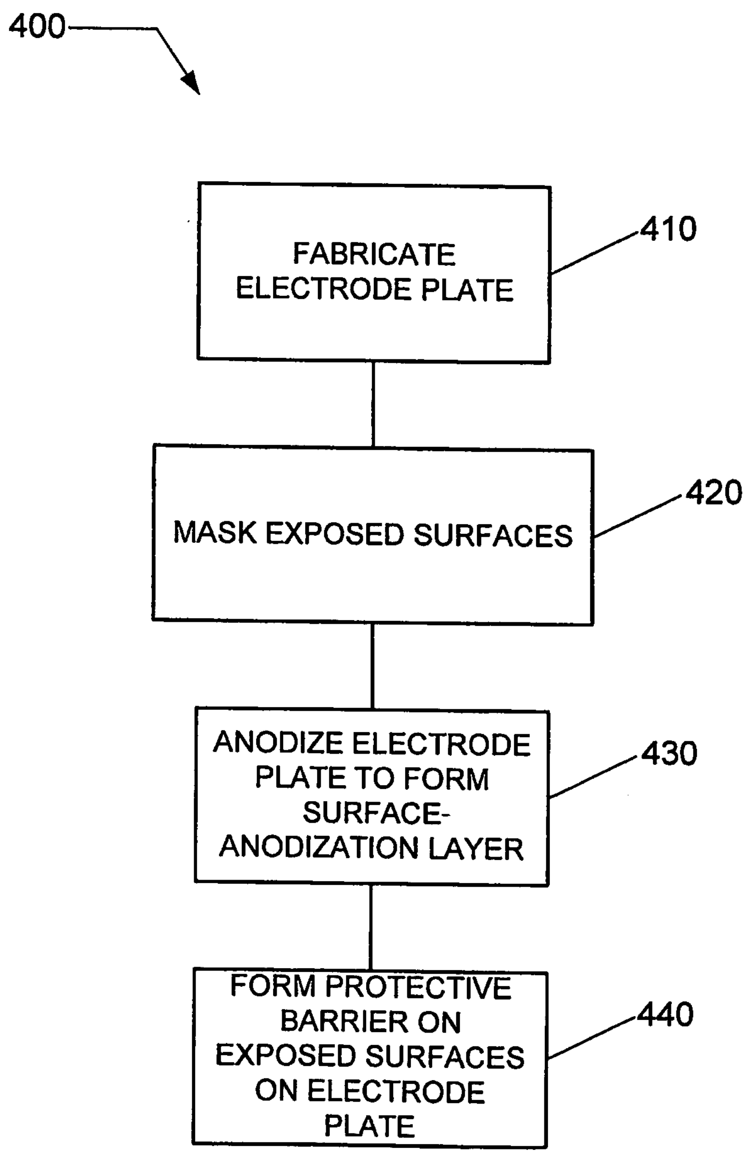

400
FABRICATE ELECTRODE PLATE
410
MASK EXPOSED SURFACES
420
ANODIZE ELECTRODE PLATE TO FORM SURFACE-ANODIZATION LAYER
430
FORM PROTECTIVE BARRIER ON EXPOSED SURFACES ON ELECTRODE PLATE
440

FIG. 8.

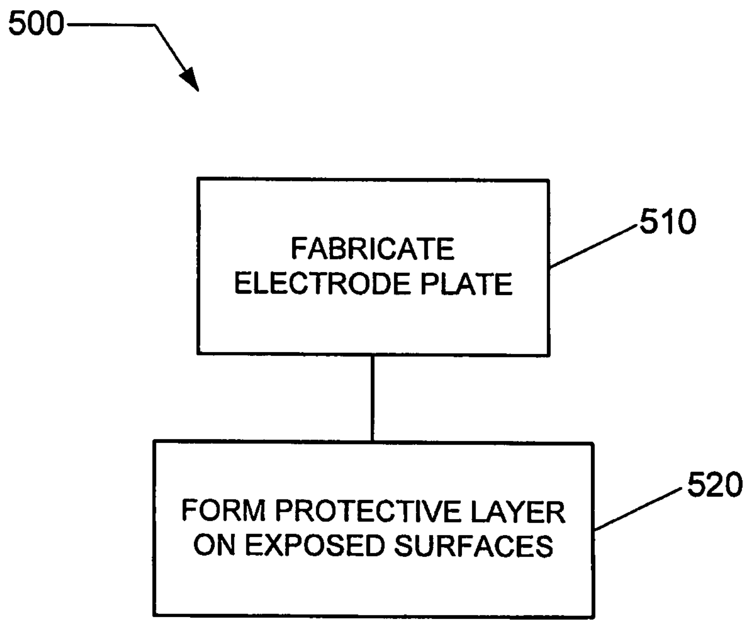

500
FABRICATE ELECTRODE PLATE
510
FORM PROTECTIVE LAYER ON EXPOSED SURFACES
520

FIG. 9.